

Mail Stop Appeal Brief - Patents

PATENT

Attorney Docket No. MTI-31529

**BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES
IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

Appellant : Ronald A. Weimer
Serial No. : 09/935,255
Filing Date : August 22, 2001
For : Method of Composite Gate Formation
Group Art Unit: 2893
Examiner : CHEN, Jack S. J.
Confirmation No.: 1208

CERTIFICATION OF SUBMISSION

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Date: March 11, 2011

Jul R. Belmatiev

Mail Stop Appeal Brief - Patents

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

APPEAL BRIEF UNDER 37 C.F.R. §41.37

Sir:

This is an appeal from the final rejection of Claims 1-5, 7-14, 16-21, 98-100, 103-106 and 112, as stated in the Office Action mailed October 15, 2010.

A Notice of Appeal was filed January 11, 2011.

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I. REAL PARTY IN INTEREST

The real party in interest is Micron Technology, Inc.

II. RELATED APPEALS AND INTERFERENCES

There is a pending appeal for related application U.S. Serial No. 10/932,130 (Notice of Appeal filed March 10, 2011).

Appellant's legal counsel: Kristine M. Strodthoff, Reg. No. 34,259, Whyte Hirschboeck Dudek S.C.

Assignee: Micron Technology, Inc.

III. STATUS OF CLAIMS

All the claims of this application and their individual status are as follows. A copy of the claims involved in the appeal is provided in the Claims Appendix.

Claims pending: 1-5, 7-57, 73, 75-81, 96 and 98-121

Claims canceled: 6, 58-72, 74, 82 and 97

Claims withdrawn from further consideration: 15, 22-57, 73, 75-81, 83-96, 101, 102, 107-111 and 113-121

Claims on appeal: 1-5, 7-14, 16-21, 98-100, 103-106 and 112

IV. STATUS OF AMENDMENTS

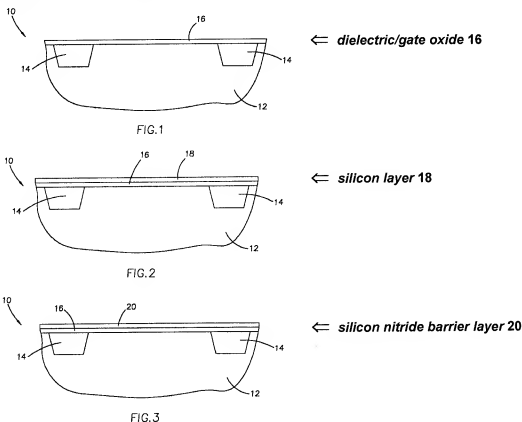
All amendments have been entered.

V. SUMMARY OF CLAIMED SUBJECT MATTER

All of the claims under appeal are drawn to various embodiments of a method of forming a silicon nitride dopant diffusion barrier layer that is effective to inhibit passage of a dopant into an underlying dielectric/oxide material.

The independent claims under appeal are 1, 5, 7-9 and 16-20.

Appellant illustrates an embodiment of the methods in Figs. 1-3 (shown below), which show forming a silicon nitride dopant diffusion barrier layer (20), as described in the specification at page 5, line 22 to page 7, line 24.



Generally, Appellant's method comprises exposing a dielectric material (16) to a silicon-containing gas under low partial pressure to deposit a silicon layer (18) over the dielectric material, and then exposing the silicon layer (18) to a nitrogen-containing gas to nitridize and form a

silicon nitride barrier layer (20) that "consists of silicon and nitrogen" and is effective to inhibit passage of a dopant (e.g., boron) into the underlying dielectric material (16).

Formation of the silicon layer (18) is illustrated in Fig. 2 and described at page 6, line 15 to page 7, line 2. Nitridizing the silicon layer (18) to convert the silicon to silicon nitride to form a dopant diffusion barrier layer (20) is illustrated in Fig. 3 and described at page 7, lines 3-22. The silicon nitride layer (20) as a barrier to inhibit passage of dopants (e.g., boron) is described at page 7, lines 23-24, and in originally filed Claim 53 (silicon nitride barrier layer to inhibit passage of the dopant from the polysilicon layer) and Claim 54 (polysilicon layer comprises a boron dopant).

Claim 1, directed to a method of forming a nitride barrier layer (20), requires exposing a dielectric material (16) to a silicon-containing gas under low partial pressure to deposit a layer of silicon (18) over the dielectric material (16), and exposing the silicon layer (18) to a nitrogen-containing gas to nitridize the silicon layer (18) to form a silicon nitride dopant diffusion barrier layer (20) consisting of silicon and nitrogen overlying and interfacing with the dielectric material (16) and effective to inhibit passage of a dopant into the underlying dielectric material (16), as described in the specification at page 6, lines 15-18 and page 7, lines 3-10 and 23-24.

Claim 5 recites the elements of Claim 1, with the exception of the terms 'irradiating' with a silicon-containing gas to 'nucleate' the dielectric material (16) with silicon, and exposing the silicon layer (18) to nitrogen-containing gas to 'form' a silicon nitride barrier layer (20), as described in the specification at page 6, lines 15-16 (irradiated; nucleate).

Claim 7 recites the elements of Claim 1, with the exception of 'nitridizing' the silicon layer (18), as described in the specification at page 7, lines 3-4.

Claim 8 recites the elements of Claim 1, with the exception of exposing a 'surface' of the dielectric material (16) to silicon-containing gas to 'nucleate' the surface of the dielectric material, as described in the specification at page 6, lines 15-17.

Claim 9 recites the elements of Claim 7, with the additional limitation of a partial pressure of about 10^{-2} Torr or less in exposing the dielectric material (16) to a silicon-containing gas, as described in the specification at page 6, lines 27-28, and with the exception of 'nitridizing the silicon layer' (18) (without reciting a nitrogen-containing gas).

Claim 16 recites the elements of Claim 8 and 9, with the exception of a limitation of a partial pressure range of about 10^{-2} to 10^{-7} Torr in exposing the dielectric material (16) to a silicon-containing gas, to 'nucleate' the dielectric layer, as described in the specification at page 6, lines 15-17 ('nucleate') and lines 27-29.

Claim 17 recites the elements of Claim 16, with the additional limitations of temperature and duration of exposing the dielectric material (16) to the silicon-containing gas, as described in the specification at page 6, line 27 to page 7, line 2.

Claim 18 recites the elements of Claim 7, with the exception of the limitation of "thermal annealing" the silicon layer (18) in nitrogen-containing gas, as described in the specification at page 2, line 27-28 and page 3, lines 8-9 and 16-17.

Claim 19 recites the elements of Claim 1, with the additional limitation of exposing the silicon layer (18) to nitrogen-containing gas at about 700-900°C, as described in the specification at page 7, lines 9-12.

Claim 20 recites the elements of Claim 19, with the additional limitations of pressure, flow rate and duration, as described in the specification at page 7, lines 9-13.

Dependent Claim 103, depends from Claim 1, and defines the step of exposing the silicon layer (18) as "thermally annealing" the silicon layer (18) in a nitrogen-containing gas, as described in the specification at page 2, line 27-28 and page 3, lines 8-9 and 16-17.

Dependent Claim 104, depends from Claim 1, and defines the step of exposing the silicon layer (18) to the nitrogen-containing gas at a temperature of about 700-900°C, as described in the specification at page 7, lines 9-12.

Dependent Claim 105, depends from Claim 1, and defines the step of exposing the silicon layer (18) to the nitrogen-containing gas at a temperature of about 700-900°C, and further defines the pressure, gas flow rate and duration, as described in the specification at page 7, lines 9-13.

VI. GROUNDS OF REJECTION TO BE REVIEWED ON APPEAL

1. Whether Claims 1, 5, 7, 8, 18, 98-100, 103 and 106 are unpatentable under 35 USC §102(b) as being anticipated by Aronowitz (USP 6,087,229).

2. Whether Claims 2-4, 9-14, 16-17, 19-21, 104-105 and 112 are unpatentable under 35 USC §103(a) as being obvious over Aronowitz (USP 6,087,229) in view of Muralidhar (USP 6,297,095).

VII. ARGUMENT

1. **Whether Claims 1, 5, 7, 8, 18, 98-100, 103 and 106 are unpatentable under 35 USC §102(b) as being anticipated by Aronowitz (USP 6,087,229).**

The Examiner finally rejected Claims 1, 5, 7, 8, 18, 98-100, 103 and 106 under 35 U.S.C. § 102(a) as anticipated by Aronowitz (USP 6,087,229).

To constitute anticipation under Section 102, each and every element of a claimed invention must be found in a single reference. *SmithKline Beecham Corp. v. Apotex Corp.*, 78 USPQ2d 1097 (Fed. Cir. 2006); *Eolas Technologies Inc. v. Microsoft Corp.*, 73 USPQ2d 1782 (Fed. Cir. 2005).

In the final Office Action, the Examiner argues that the intermediate silicon nitride layer **206** illustrated in **Fig. 2D**, is a "dopant diffusion barrier layer" that intrinsically (inherently) inhibits the passage of a dopant into the dielectric layer (204) – and therefore anticipates Appellant's methods as claimed. (Final Office Action at pages 2-3, bridging paragraph; emphasis added.)

...and exposing the silicon layer to a nitrogen-containing gas to nitridize the silicon layer to form a continuous silicon nitride *dopant diffusion* barrier layer **206** over the dielectric material effective to inhibit passage of a dopant (note: this is the intrinsic properties of the nitride material, *also see col. 8, first paragraph and lines 37-34...*) therethrough into the dielectric material (**fig. 2D**), the dopant diffusion barrier layer consisting of silicon and nitrogen overlying and interfacing with the dielectric material (i.e., SiN, see **Fig. 2D**), see figs. 1A-5D and cols. 1-10 for more details....

In support of his inherency argument, the Examiner cites to Aronowitz at col. 8, lines 27-34 for teaching that inhibiting passage of a dopant is "the intrinsic properties of the nitride material" (*layer 206 in Fig. 2D*).

The Examiner further cites to Sugita (USP 6,998,303) at col. 3, lines 60-66, as "evidence" of the intrinsic properties of the nitride layer **206** in **Fig. 2D** of Aronowitz. (Final Office Action at page 3, lines 2-4.)

The Examiner also argues that the limitation 'effective to inhibit passage of a dopant (e.g., boron) therethrough' is merely functional language and/or an intended use limitation. (Final Office Action at page 3, lines 6-9.)

The Examiner's rejection of the claims is in error because:

- a) The Examiner has mischaracterized Aronowitz' disclosure of a boron diffusion barrier layer;
 - b) Sugita does not support the Examiner's inherency argument;
 - c) Publications refute the Examiner's inherency argument;
 - d) The Examiner has failed to properly consider the limitations of independent Claim 18 and dependent Claim 103;
 - e) Aronowitz does not teach forming a silicon nitride layer 'consisting of silicon and nitrogen' and 'interfacing with' a dielectric material; and
 - f) The claim limitation "effective to inhibit passage of a dopant therethrough" is not merely a functional limitation.
- a) **The Examiner has mischaracterized Aronowitz' disclosure of a boron diffusion barrier layer.**

Aronowitz does not teach that silicon nitride layer **206** of **Fig. 2D** is inherently an effective boron diffusion barrier.

In relying upon the theory of inherency, the Examiner must provide factual and technical grounds to support the determination that the allegedly inherent characteristic *necessarily and inevitably* results from the applied prior art. Inherency may not be established by probabilities or possibilities. That a certain result or characteristic *may* result from a given set of circumstances is not sufficient to establish the inherency of that result or characteristic. *SmithKline Beecham Corp. v. Apotex Corp.*, 74 USPQ2d 1396 (Fed. Cir. 2005); *In re Robertson*, 49 USPQ2d 1949, 1950-51 (Fed. Cir. 1999); *Continental Can Company USA v. Monsanto Company*, 20 USPQ2d 1746 (Fed. Cir. 1991); *In re Oelrich*, 212 USPQ 323, 326 (CCPA 1981).

For the doctrine of inherency to apply it must be inevitable that Aronowitz' process to form the intermediate silicon nitride layer (**206**) in **Fig. 2D** necessarily results in a silicon nitride layer that will effectively function as a barrier layer to inhibit diffusion of a dopant (e.g., boron) therethrough to an underlying dielectric material.

Aronowitz forms the intermediate silicon nitride layer (206) in Fig. 2D by implanting nitrogen (N_2) into a silicon (Si) layer – denoted below as "Si \rightarrow SiN".

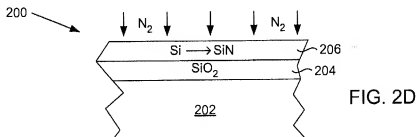


FIG. 2D

The Examiner argues that the intermediate silicon nitride layer (206) in Fig. 2D inherently inhibits passage of a dopant therethrough – citing to Aronowitz at col. 8, lines 1-16 and 27-34.

However, at col. 8, lines 1-16 and 27-34, Aronowitz addresses a silicon oxynitride (SiO_xN_y) layer 406 illustrated in Fig. 4D below – not the intermediate silicon nitride (SiN) layer 206 of Fig. 2D.

See Fig. 4D and col. 8, lines 1-25 of Aronowitz, which is cited by the Examiner (emphasis added).

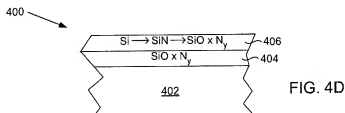


FIG. 4D

...Alternatively, as shown in FIG. 4D, the thin silicon layer 406 may also be subjected to low energy plasma nitridization and then oxidized to create a thin composite dielectric having two oxynitride layers. This second procedure provides the added benefit of preventing deterioration in dielectric properties by providing a nitrogen barrier to diffusion of boron from the gate electrode into the dielectric...

The double oxynitride layer-producing embodiment may be particularly useful *where a very effective barrier layer is desired*, such as where very thin polysilicon gates (for example, less than about 150 nm) with *high boron dose implants* are used. ...

As shown in Fig. 4D, Aronowitz forms layer 406 by nitridizing silicon and then oxidizing the silicon nitride (SiN) to form silicon oxynitride 406 – as signified by Si \rightarrow SiN \rightarrow SiO_xN_y .

And – at col. 8, lines 1-25, Aronowitz specifically teaches that forming the oxidized SiO_xN_y layer **406** on an underlying oxidized SiO_xN_y layer **404** achieves an effective barrier to boron diffusion.

The claims at issue require forming a dopant diffusion barrier layer *consisting of* silicon and nitrogen – which eliminates the presence of oxygen and a silicon oxynitride layer.

Aronowitz provides no teaching that *intermediate* SiN layer **206** (**Fig. 2D**) would inherently be an effective boron diffusion barrier without the additional oxidation step as described at col. 8, lines 1-10.

The only teachings in Aronowitz of a boron diffusion barrier are:

- (a) the background description of the prior art to suppress boron diffusion by diffusing nitrogen into a gate oxide at a high temperature (at col. 2, lines 9-18) and implanting nitrogen into a polysilicon gate electrode (at col. 2, lines 33-52); and
- (b) the formation of the oxidized silicon oxynitride layer **406** of **Fig. 4D** at col. 8, lines 3-10 (cited by the Examiner).

Nowhere does Aronowitz teach or suggest that the intermediate SiN layer (**206**) (**Fig. 2D**) is inherently an effective dopant (boron) diffusion barrier.

In fact, Aronowitz' disclosure at col. 8, lines 3-10 (cited by the Examiner), clearly teaches that *oxidation* of the intermediate silicon nitride layer **206** (**Fig. 2D**) is required to achieve dopant barrier properties.

The Examiner has provided no evidence or reasoning that Aronowitz' intermediate SiN layer **206** (**Fig. 2D**) would inherently be an effective boron diffusion barrier without the additional oxidation as specifically taught by Aronowitz at col. 8, lines 1-10.

b) Sugita does not support the Examiner's inherency argument.

The Examiner further relies on Sugita (USP 6,998,303) at col. 3, lines 60-66, as "evidence" of the intrinsic properties of the nitride layer **206** in **Fig. 2D** of Aronowitz. (Final Office Action at page 3, lines 2-4.)

Sugita is not prior art to the application. Sugita was filed August 2003. The present application has a filing date of August 2001. Therefore, Sugita is improperly cited by the Examiner.

Furthermore, even if, *arguendo*, one were to consider Sugita's disclosure, it does not support the Examiner's argument that the intermediate silicon nitride layer (**206**) in **Fig. 2D** of Aronowitz is inherently effective as a dopant (boron) diffusion layer.

Sugita's disclosure at col. 2, lines 60-66, merely states that a silicon nitride film having a thickness of 0.5 to 1 nm can be formed between a gate insulating film and polysilicon film to suppress boron diffusion (emphasis added).

The processes up to the state shown in FIG. 1B will be described. A polysilicon film is deposited on the gate insulating film 5 to a thickness of 40 to 120 nm. *In order to suppress the diffusion of boron, a silicon nitride film or silicon oxynitride film having a thickness of 0.5 to 1 nm may be formed between the gate insulating film 5 and polysilicon film.*

That teaching by Sugita does not establish that the intermediate silicon nitride layer **206** in **Fig. 2D** of Aronowitz is necessarily and inherently an effective dopant (boron) diffusion layer as argued by the Examiner – particularly in view of Aronowitz' teaching at col. 8, lines 1-25 (cited by the Examiner) that it is through *oxidizing* silicon nitride and providing a double oxynitride layer – i.e., SiO_xN_y layers **404**, **406** in **Fig. 4D** – that a boron diffusion barrier layer is formed in Aronowitz' construction.

e) Publications refute the Examiner's inherency argument.

It is further recognized in the art that an anneal of a silicon nitride material is needed to form the SiN material into an effective 'dopant diffusion barrier layer.'

The need for an anneal to form an effective 'dopant diffusion barrier layer' after nitridation of silicon material is evidenced, for example, by USP 6,410,968 (Powell et al.), which was cited by Appellant in the Response filed December 15, 2010 (at pages 4-5); submitted in IDS filed July 30, 2010).

See USP 6,410,968 (Powell) at col. 3, lines 8-43 below (emphasis added).

...A silicon-containing material is vapor deposited onto the surface of the wafer at block 203 from a silicon source. *The silicon-containing material is treated or processed using rapid thermal nitridation (RTN) in an NH₃ ambient at block 204 resulting in creation of the barrier layer. The temperature, anneal time and processing pressure are selected to obtain desired barrier layer characteristics.* ...

...FIG. 2B illustrates that *a suitable barrier layer may be formed at about 450 Torr and 850°C.*, over a processing time of 60 seconds with minimal oxidation of the underlying silicon substrate. It is noted that the 850°C. processing temperature is lower than *the processing temperature (typically 950°C.) used to create barrier layers using conventional methods*. In addition, the 60 seconds processing time is lower than the processing time used to create barrier layers using conventional methods (typically 45 minutes). ...

Generally, conventional barrier layers are processed using temperature ranges of 700°C. to 1050°C., processing time of 10 seconds to 60 minutes, and processing pressure of 760 torr. Whereas, the barrier layer of the present invention is typically processed using temperature ranges of *500°C. to 900°C.*, processing time of 30 seconds to 5 minutes, and processing pressure of 450 torr. ...

See also US 2008/0268634 (Yang) – at paragraphs [0007] and [0021], which teaches implanting nitrogen and annealing the structure to form a boron diffusion barrier layer (at the interface between a silicon layer and oxide layer), which was cited by Appellant in the Response filed December 15, 2010 (at page 5); submitted in IDS filed July 30, 2010).

[0007] ...wherein the diffusion barrier layer is formed by implanting nitrogen into an interface region between the silicon layer and the buried oxide layer and annealing the structure to form the diffusion barrier layer between the buried oxide layer and the silicon layer.

[0021] ...*Diffusion barrier layer 214 is formed by implanting nitrogen into interface region 205 between silicon layer 206 and buried oxide layer 204 and annealing 212 (FIG. 7) structure 200 to form diffusion barrier layer 214* between buried oxide layer 204 and silicon layer 206. As shown in FIGS. 6-7, oxygen 208 (FIG. 6) and *nitrogen 210 (FIG. 7) are implanted* into structure 200 following the formation of silicon layer 206. This oxygen/nitrogen ion beam implantation process is *followed by a high temperature anneal 212 (FIG. 7) to create* buried SiO₂ layer 204 and *diffusion barrier layer 214*, respectively. Diffusion barrier layer 214 effectively inhibits the diffusion of boron into regions underlying diffusion barrier layer 214.

In contrast, Aronowitz does not teach thermally annealing the silicon nitride intermediate layer **206 of Fig. 2D**.

To form the intermediate silicon nitride (SiN) layer **206 (Fig. 2D)**, Aronowitz implants nitrogen into the silicon layer. However, Aronowitz does not teach performing an anneal of the intermediate SiN material **206 (Fig. 2D)**. See Aronowitz at col. 5, line 57 to col. 6, line 34, as follows (emphasis added).

The thin silicon film 206 may then be nitridized, as shown in FIG. 2D. According to a preferred embodiment of the present invention, the wafer 200 may be introduced into a plasma reactor (not shown), such as one that is normally used for plasma etching of polysilicon. Suitable reactors can generate a plasma density and energy appropriate for the creation of ionic species having energies sufficient to break silicon-silicon bonds and penetrate the surface of the polysilicon film 206 without substantially damaging its structure. A relatively high density, such as about $10^{10}/\text{cm}^3$ to $10^{13}/\text{cm}^3$, and low energy, such as less than about 12 eV, preferably between about 5 and 10 eV, which can be separately controlled by the reactor, are preferred. The LAM 9400SE is an example of such a reactor. Molecular nitrogen may be introduced into the reactor to form the plasma containing nitrogen species which have energies of less than about 20 eV, and which are sufficient to break silicon-silicon bonds so that these nitrogen (atomic and/or molecular) entities react at the surface of the polysilicon film 206 and within several atomic layers into the film producing a nitrogen-rich surface region in the polysilicon film 206.

...

For example, a LAM 9400SE reactor may be operated according to the following process parameters to achieve nitridization of a thin amorphous or poly silicon film deposited on an oxide, according to a preferred embodiment of the present invention: pressure of about 10 mtorr; N_2 flow rate of about 10 standard cubic centimeters per minute (sccm); TCP power of about 200 W; bias power of about 10 W; electrode temperature of about 60°C .; backside He pressure of about 8 torr; step time of about 10 minutes. Using these parameters, a plasma with about 10 eV nitrogen species may be produced resulting in nitridization of the thin silicon film to about 25 to 30 atomic percent.

No anneal of the intermediate SiN layer **206** is performed or taught by Aronowitz which would form the SiN layer **206** into an effective boron diffusion barrier layer. Instead, following the nitridization step (**Fig. 2D**), Aronowitz teaches oxidizing the intermediate SiN layer **206** to convert it into a silicon oxynitride (SiO_xN_y) layer **206** in **Fig. 2E**, as described at col. 6, lines 51-64 as a 'hardened composite gate dielectric.'

Merely implanting nitrogen into silicon by Aronowitz' conditions does not inherently produce an effective boron barrier layer. As evidenced above and taught by Aronowitz, an anneal of the intermediate SiN layer **206 (Fig. 2D)** would be required to form an effective dopant diffusion barrier – e.g., a thermal anneal – or oxygen anneal as used by Aronowitz to produce a silicon oxynitride (SiO_xN_y) layer **406** in **Fig. 4D**.

In sum, the Examiner has provided no evidence of the intrinsic properties of intermediate silicon nitride layer **206** in **Fig. 2D** of Aronowitz as a dopant diffusion barrier layer.

Aronowitz does not teach forming a silicon nitride layer that consists of silicon and nitrogen – and is effective to inhibit passage of a dopant (e.g., boron) therethrough to an underlying dielectric material as required by the claims.

d) The Examiner has failed to properly consider the limitations of independent Claim 18 and dependent Claim 103.

Claims 18 and 103 define methods that require *thermally annealing* the silicon layer in a nitrogen-containing gas to form the nitride dopant diffusion barrier layer.

Regarding Claim 18, the Examiner argues that Aronowitz discloses "thermally annealing" the silicon layer **206** in a nitrogen-containing gas. (Final Office Action at page 4, lines 8-10.)

Regarding Claim 103, the Examiner cites to cols. 5-6 of Aronowitz for teaching "thermally annealing/nitridization" of the silicon layer in a nitrogen-containing gas. (Final Office Action at page 5, lines 6-7.)

To the contrary, Aronowitz does not teach thermally annealing a silicon layer to form the silicon nitride (SiN) intermediate layer **206** of **Fig. 2D**. See Aronowitz at col. 5, line 57 to col. 6, line 34. Aronowitz implants nitrogen into the silicon layer – but does not perform a thermal anneal in forming the silicon nitride intermediate material **206** (**Fig. 2D**).

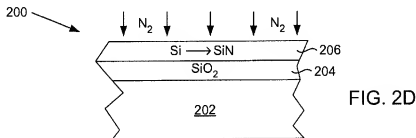
The Examiner has failed to indicate where Aronowitz teaches '*thermally annealing*' the silicon layer to form SiN layer **206** (**Fig. 2D**).

Aronowitz does not teach Appellant's method of forming a dopant diffusion barrier layer consisting of silicon and nitrogen by *thermally annealing* a silicon layer in a nitrogen-containing gas, as required in Claims 18 and 103.

e) Aronowitz does not teach forming a silicon nitride layer 'consisting of silicon and nitrogen' and 'interfacing with' a dielectric material.

The claims define Appellant's methods as forming a dopant diffusion barrier layer 'consisting of nitrogen and silicon' (i.e., no oxygen) overlying and *interfacing with a dielectric material*.

As discussed above, Aronowitz forms the intermediate silicon nitride layer (206) in **Fig. 2D** by implanting nitrogen ($N_2 \downarrow$) into a silicon (Si) layer – denoted below as "Si \rightarrow SiN".



Aronowitz teaches implanting the nitrogen to produce a 'nitrogen-rich surface' resulting in a N-gradient that goes from a N-rich surface to little or no nitrogen at the interface with the silicon oxide layer 204. See Aronowitz' illustration of the N-gradient in **Fig. 3** (below) and the discussion at col. 6, lines 7-10 and 35-50 (emphasis added).

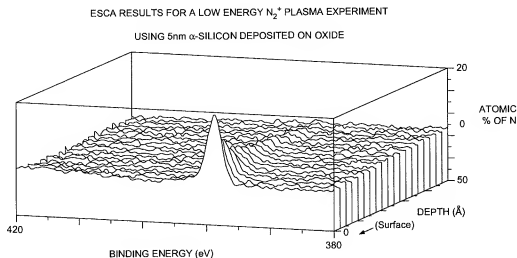


FIG. 3

...so that these nitrogen (atomic and/or molecular) entities react at the surface of the polysilicon film 206 and within several atomic layers into the film producing a nitrogen-rich surface region in the polysilicon film 206.

FIG. 3 shows a three-dimensional representation of the results an electron spectroscopic chemical analysis (ESCA) for a low energy nitrogen plasma implant using the parameters described above. The vertical axis represents atomic percent of nitrogen, and the side axis represents the depth of the thin silicon layer, starting from the surface and moving down. ...The results demonstrate that nitrogen is implanted according to a gradient from the surface of the silicon film, which is about 20 atomic percent nitrogen, to the interface with the oxide,

which has very little or no nitrogen content. These results illustrate another useful feature of the present invention, which is that the nitrogen which hardens the dielectric layer is isolated from the underlying oxide and substrate layers and does not affect their performance.

Aronowitz specifically points out that a "useful feature" of the invention is nitridizing the silicon layer such that nitrogen "is isolated from the underlying oxide."

Clearly, Aronowitz' nitridization process does not produce a silicon nitride layer that interfaces with a dielectric material as required by the claims. Rather, Aronowitz' teaches a nitridization of the silicon layer (206 in Fig. 2C) to produce a silicon nitride (SiN) intermediate layer **206 (Fig. 2D)** that is *isolated* from the underlying SiO₂ layer **204** with a layer of silicon remaining between.

f) The claim limitation "effective to inhibit passage of a dopant therethrough" is not merely a functional limitation.

The Examiner has incorrectly interpreted the limitation in the claims of "effective to inhibit passage of a dopant (e.g., boron) therethrough" as merely functional language or intended use with no limitation of structure.

There is nothing inherently wrong with defining some part of an invention in functional terms. A functional limitation define something by what it does rather than by what it is (e.g., a specific structure or specific ingredients). Functional language does not, in and of itself, render a claim improper. *In re Swinehart*, 169 USPQ 226 (CCPA 1971).

A functional limitation must be evaluated and considered, just like any other limitation of the claim, for what it fairly conveys to a person of ordinary skill in the pertinent art in the context in which it is used. A functional limitation is often used in association with an element, ingredient, or step of a process to define a particular capability or purpose that is served by the recited element, ingredient or step.

The claim limitation "effective to inhibit passage of a dopant (e.g., boron) therethrough" is not merely a functional limitation. Rather, the term relates directly to the recited step of exposing the silicon layer to a nitrogen-containing gas (or nitridizing the silicon layer in a nitrogen-containing gas as in Claims 7 and 9; or thermally annealing the silicon layer in a nitrogen-containing gas as defined in Claim 18 and dependent Claim 103) to form a silicon

nitride layer consisting of silicon and nitrogen that has the structural attributes of a dopant diffusion barrier. The claim limitation "effective to inhibit passage of a dopant (e.g., boron) therethrough" is directly tied to the make-up and chemical structure of the silicon nitride layer that is produced according to Appellant's methods by the nitridation of the silicon layer.

Although a functional limitation, it sets definite boundaries on the process step of Appellant's claims to produce a material consisting of a silicon and nitrogen that is structured to inhibit diffusion and passage of a dopant (e.g., boron) through the layer – eliminating inoperative silicon nitride layers that do not perform the same way and accomplish the same result as a dopant diffusion barrier layer, and which are not embraced by the claims. One skilled in the art would readily understand from the claim terms whether a method step and silicon nitride layer produced by that method step is encompassed by the claims.

The Examiner has failed to properly consider the claim limitation 'effective to inhibit passage of a dopant (e.g., boron) therethrough' in the claims.

In sum, the intermediate SiN layer **206** of **Fig. 2D** formed by Aronowitz is not inherently a dopant diffusion barrier layer that is 'effective to inhibit passage of a dopant (e.g., boron) therethrough,' as required by the claims. As discussed above, Aronowitz only teaches the *oxidized* silicon oxynitride (SiO_xN_y) layer **406** (**Fig 4D**) as a boron diffusion barrier layer. The Examiner has failed to provide any support for his argument that the intermediate silicon nitride layer **206** in **Fig. 2D** of Aronowitz is inherently a dopant diffusion barrier layer.

In addition, Aronowitz does not teach silicon nitride layer **206** (**Fig. 2D**) interfacing with a dielectric material as required by the claims. Nor does Aronowitz teach thermally annealing a silicon layer in nitrogen-containing gas as required in Claims 18 and 103.

Aronowitz does not teach Appellant's methods of forming a nitride barrier layer that require exposing a silicon layer to a nitrogen-containing gas to result in a silicon nitride layer having a structure that consists of silicon and nitrogen interfacing with a dielectric material – and is an effective barrier to inhibit diffusion and passage of dopants such as a boron therethrough.

As such, Aronowitz cannot anticipate any of the claims at issue.

2. Whether Claims 2-4, 9-14, 16, 17, 19-21, 104, 105 and 112 are unpatentable under 35 USC §103(a) as being obvious over Aronowitz (USP 6,087,229) in view of Muralidhar (USP 6,297,095).

The Examiner finally rejected Claims 2-4, 9-14, 16, 17, 19-21, 104, 105 and 112 as obvious over Aronowitz (USP 6,087,229) in view of Muralidhar (USP 6,297,095). (Final Office Action at pages 6-11.)

The Examiner maintains that Aronowitz is "silent" regarding the 'claimed conditions' and cites to Muralidhar for disclosing various process parameters as defined in the claims. In particular, the Examiner cites to Figs. 23-25 of Muralidhar and at col. 16, lines 19-36, for describing the formation of a silicon nitride "barrier" layer **106/107**. The Examiner argues that it would have been obvious to utilize the processing conditions described by Muralidhar in the method of Aronowitz in order to produce a silicon nitride barrier layer. (Final Office Action at page 9, lines 11-14.)

The Examiner further argues that Muralidhar's SiN layer **106/107** is *intrinsically* effective to inhibit passage of a dopant therethrough. In support of that argument, the Examiner cites *inclusively* to all of Figs. 1-28 and cols. 1-22 – which is Muralidhar *entire* disclosure. (Final Office Action at page 6, lines 14-17.)

The Examiner's rejection of the claims is in error because:

- a) One skilled in the art reading Aronowitz's disclosure would not modify the processing parameters as proposed by the Examiner; and
 - b) There is no teaching in Muralidhar of either silicon nitride layer 106 or 107 as an effective dopant diffusion barrier.
- a) One skilled in the art reading Aronowitz's disclosure would not modify the processing parameters as proposed by the Examiner.**

At col. 16, lines 19-36 (cited by the Examiner), Muralidhar discloses processing conditions for forming a thin, silicon nitride encapsulation layer **106** over the surface of silicon nanoclusters by *flowing a nitriding ambient* (e.g. ammonia) over silicon nanoclusters at high temperature (700-1000°C), i.e., an ammonia anneal.

See below and **Fig. 23** (emphasis added).

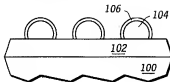


FIG. 23

Further processing steps can be performed in order to limit the oxidation or other degradation of the nanoclusters due to ambient exposure. **FIG. 23** illustrates the nanocluster structures of FIG. 22 following an encapsulation step. The encapsulation step forms an encapsulation layer 106 on each of the nanoclusters **104**. Such an encapsulation layer **106** may be formed of silicon nitride. Silicon nitride may be formed on the surface of the nanoclusters **104** by exposing the nanoclusters **104** to a nitriding ambient at high temperature. Such an ambient may include ammonia, nitrous oxide, or other nitrogen-containing compounds that are reactive to silicon in a manner that can be controlled. In one embodiment, a thin layer of nitride is formed on the nanoclusters by flowing ammonia, without other reactants, over the nanoclusters. The conditions under which the ammonia may be flowed may include a temperature within a typical range of 700-1000 degrees Celsius and a pressure within a typical range of 1-760 Torr.

First of all, Aronowitz addresses the drawbacks of conventional nitridization methods in the background section at cols. 1-3.

At col. 2, lines 9-32, Aronowitz specifically addresses drawbacks of thermal nitridation processes, e.g., an ammonia anneal at high temperature treatment (about 900°C) to diffuse nitrogen into a gate oxide – which introduces electron traps into the dielectric and increases the fabrication process thermal budget.

Second, the stated objective of Aronowitz is "avoiding the drawbacks of prior art nitridization methods." See Aronowitz at col. 3, lines 43-57 and at col. 5, lines 4-15.

And – contrary to the Examiner's argument, Aronowitz is not silent as to the processing conditions for forming the intermediate silicon nitride SiN layer **206** (**Fig. 2D**).

To avoid the drawbacks of prior art nitridization methods, Aronowitz specifically teaches the use of a low energy nitrogen plasma implantation to nitridize the silicon film with specific processing conditions for implanting the nitrogen. Aronowitz particularly teaches using that process and the stated conditions to produce a decreasing nitrogen gradient from the surface of the silicon film to the underlying silicon oxide interface whereby nitrogen is isolated from the underlying oxide layer – a stated "feature" of the invention.

See Fig. 3 above and the discussion in Aronowitz at col. 6, lines 3-10 and 23-50 (emphasis added).

...Molecular nitrogen may be introduced into the reactor to form the plasma containing nitrogen species which have energies of less than about 20 eV, and which are sufficient to break silicon-silicon bonds so that these nitrogen (atomic and/or molecular) entities react at the surface of the polysilicon film 206 and within several atomic layers into the film producing a nitrogen-rich surface region in the polysilicon film 206.

...
For example, a LAM 9400SE reactor may be operated according to the following process parameters to achieve nitridization of a thin amorphous or poly silicon film deposited on an oxide, according to a preferred embodiment of the present invention: *pressure of about 10 mtorr; N₂ flow rate of about 10 standard cubic centimeters per minute (sccm); TCP power of about 200 W; bias power of about 10 W; electrode temperature of about 60°C.; backside He pressure of about 8 torr; step time of about 10 minutes. Using these parameters, a plasma with about 10 eV nitrogen species may be produced resulting in nitridization of the thin silicon film to about 25 to 30 atomic percent.*

FIG. 3 shows a three-dimensional representation of the results an electron spectroscopic chemical analysis (ESCA) *for a low energy nitrogen plasma implant using the parameters described above.* The vertical axis represents atomic percent of nitrogen, and the side axis represents the depth of the thin silicon layer, starting from the surface and moving down. The horizontal axis represents the binding energy of core electrons. *The results demonstrate that nitrogen is implanted according to a gradient from the surface of the silicon film, which is about 20 atomic percent nitrogen, to the interface with the oxide, which has very little or no nitrogen content. These results illustrate another useful feature of the present invention, which is that the nitrogen which hardens the dielectric layer is isolated from the underlying oxide and substrate layers and does not affect their performance.*

Aronowitz does not teach the use of an ammonia anneal – and particularly not the use of a high temperature in nitridizing the silicon layer.

In contrast, Muralidhar's processing conditions for nitridizing silicon is by high temperature ammonia anneal.

One skilled in the art reading Aronowitz's disclosure including the background section which addresses the disadvantages of a high temperature ammonia anneal and the teachings of Aronowitz to form the silicon nitride intermediate layer by low energy nitrogen plasma implantation to produce a decreasing nitrogen gradient in the SiN layer would not modify the nitridization process of Aronowitz based on Muralidhar's teachings as proposed by the Examiner.

In particular, based on Aronowitz' disclosure, a skilled art worker would not modify Aronowitz' nitridization process from a low energy plasma implantation to a high temperature

anneal by exposure of the silicon layer to a nitrogen-containing gas at a temperature of about 700-900°C, as required by depending Claims 104 and 105.

b) **There is no teaching in Muralidhar of either silicon nitride layer 106 or 107 as an effective dopant diffusion barrier.**

Nor has Examiner established that the proposed modification of Aronowitz with Muralidhar would intrinsically or inherently result in a silicon nitride layer as an effective *dopant barrier*.

Muralidhar's nitride layers **106/107** are only taught as a barrier to oxygen – not as a dopant diffusion barrier. This is clearly stated by Muralidhar at col. 17, lines 1-12 and 28-40 (emphasis added). See also at col. 5, lines 35-39 ("in order to prevent oxidation...").

...By including the encapsulation layer **106**, oxidation or other degradation due to oxidizing ambient exposure of the nanoclusters **104** can be reduced or eliminated. As such, the diameter of the nanoclusters **104** is maintained, and no uncontrolled increase in the underlying tunnel dielectric occurs.

...
The thin nitride layer **107** illustrated in **FIG. 25** forms a barrier to oxygen such that both the nanoclusters **104** and the underlying semiconductor substrate **100** below the tunnel dielectric layer **102** are protected from oxidation. As such, the potential for an increase in the thickness of the tunnel dielectric layer **102** is reduced.

There is no teaching in Muralidhar of either SiN layer **106** or **107** as an effective dopant diffusion barrier.

In sum, the Examiner has failed to establish a *prima facie* case of obviousness based on the combination of Aronowitz with Muralidhar's disclosure.

Accordingly, reconsideration and then withdrawal of this rejection of the claims is respectfully requested.

Extension of Term.

The proceedings herein are for a patent application and the provisions of 37 CFR § 1.136 apply. Appellant believes that no extension of term is required, but conditionally petitions for an extension of time if so required. If any extension and/or fee are required, please charge Account No. 23-2053.

For the reasons stated in the above arguments, Appellant believes that the claims on appeal comply with 35 U.S.C. §§ 102/103, and requests that the final rejection of the claims on appeal be reversed.

Respectfully submitted,



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VIII. CLAIMS APPENDIX

The claims on appeal are:

1. A method of forming a nitride barrier layer, comprising:
exposing a dielectric material to a silicon-containing gas under low partial pressure to deposit a continuous layer of silicon over the dielectric material; and
exposing the silicon layer to a nitrogen-containing gas to nitridize the silicon layer to form a continuous silicon nitride dopant diffusion barrier layer effective to inhibit passage of a dopant therethrough into the dielectric material, the dopant diffusion barrier layer consisting of silicon and nitrogen overlying and interfacing with the dielectric material.
2. The method of Claim 1, wherein the dielectric material is exposed to the silicon-containing gas at a partial pressure of about 10^{-2} Torr or less.
3. The method of Claim 1, wherein the dielectric material is exposed to the silicon-containing gas at pressure of about 10^{-2} to about 10^{-7} Torr.
4. The method of Claim 2, wherein the dielectric material is exposed to the silicon-containing gas at a temperature of about 500°C to about 700°C.
5. A method of forming a nitride barrier layer, comprising:
irradiating a dielectric material with a silicon-containing gas under low partial pressure to nucleate the dielectric material with a continuous layer of silicon; and

exposing the silicon layer to a nitrogen-containing gas to form a continuous silicon nitride dopant diffusion barrier layer effective to inhibit passage of a dopant therethrough into the dielectric material, the dopant diffusion barrier layer consisting of silicon and nitrogen overlying and interfacing with the dielectric material.

7. A method of forming a nitride barrier layer, comprising:

exposing a dielectric material to a silicon-containing gas under low partial pressure to deposit a continuous layer of silicon over the dielectric material; and

nitridizing the silicon layer in a nitrogen-containing gas to form a continuous silicon nitride dopant diffusion barrier layer effective to inhibit passage of a dopant therethrough into the dielectric material, the dopant diffusion barrier layer consisting of silicon and nitrogen overlying and interfacing with the dielectric material.

8. A method of forming a nitride barrier layer, comprising:

exposing a surface of a dielectric material to a silicon-containing gas at a low partial pressure to nucleate the surface of the dielectric material and form a continuous layer of silicon thereon; and

exposing the silicon layer to a nitrogen-containing gas to form a continuous silicon nitride dopant diffusion barrier layer effective to inhibit passage of a dopant therethrough into the dielectric material, the dopant diffusion barrier layer consisting of silicon and nitrogen overlying and interfacing with the dielectric material.

9. A method of forming a nitride barrier layer, comprising:
exposing a dielectric material to a silicon-containing gas at a partial pressure of about 10^{-2} Torr or less to deposit a continuous layer of silicon thereon; and
nitridizing the silicon layer to form a continuous silicon nitride dopant diffusion barrier layer effective to inhibit passage of a dopant therethrough into the dielectric material, the dopant diffusion barrier layer consisting of silicon and nitrogen overlying and interfacing with the dielectric material.
10. The method of Claim 9, wherein the dielectric material is exposed to the silicon-containing gas at a temperature of about 500°C to about 700°C.
11. The method of Claim 9, wherein the silicon-containing gas is selected from the group consisting of dichlorosilane, silicon tetrachloride, silane, and disilane.
12. The method of Claim 9, wherein exposing the dielectric material to the silicon-containing gas is by plasma enhanced chemical vapor deposition, low pressure chemical vapor deposition, or rapid thermal chemical vapor deposition.
13. The method of Claim 9, wherein the silicon-containing gas is deposited by rapid thermal chemical vapor deposition at about 500°C. to about 700°C.
14. The method of Claim 9, wherein the dielectric material comprises silicon dioxide.

16. A method of forming a nitride barrier layer, comprising:

exposing a dielectric material to a silicon-containing gas at a partial pressure of about 10^{-2} to about 10^{-7} Torr to nucleate the dielectric material and form a continuous layer of silicon; and
exposing the silicon layer to a nitrogen-containing gas to form a continuous silicon nitride dopant diffusion barrier layer effective to inhibit passage of a dopant therethrough into the dielectric material, the dopant diffusion barrier layer consisting of silicon and nitrogen overlying and interfacing with the dielectric material.

17. A method of forming a nitride barrier layer, comprising:

exposing a dielectric material to a silicon-containing gas at a partial pressure of about 10^{-2} to about 10^{-7} Torr, a temperature of about 500°C. to about 700°C., and a duration of about 1 second to about 5 minutes, to nucleate the dielectric material and form a continuous layer of silicon; and

exposing the silicon layer to a nitrogen-containing gas to form a continuous silicon nitride dopant diffusion barrier layer effective to inhibit passage of a dopant into the dielectric material, the dopant diffusion barrier layer consisting of silicon and nitrogen overlying and interfacing with the dielectric material.

18. A method of forming a nitride dopant diffusion barrier layer, comprising:

depositing a continuous silicon layer onto a dielectric material by exposing the dielectric material to a silicon-containing gas under low partial pressure; and

thermally annealing the silicon layer in a nitrogen-containing gas to form the nitride dopant diffusion barrier layer, said barrier layer effective to inhibit passage of a dopant into the dielectric material, the dopant diffusion barrier layer consisting of silicon and nitrogen overlying and interfacing with the dielectric material.

19. A method of forming a nitride dopant diffusion barrier layer, comprising:

depositing a continuous silicon layer onto a dielectric material by exposing the dielectric material to a silicon-containing gas under low partial pressure; and

exposing the silicon layer to a nitrogen-containing gas at a temperature of about 700°C. to about 900°C. to nitridize the silicon layer to form the nitride dopant diffusion barrier layer, said barrier layer effective to inhibit passage of a dopant into the dielectric material, the dopant diffusion barrier layer consisting of silicon and nitrogen overlying and interfacing with the dielectric material.

20. A method of forming a nitride dopant diffusion barrier layer, comprising:

depositing a continuous silicon layer onto a dielectric material by exposing the dielectric material to a silicon-containing gas under low partial pressure; and

exposing the silicon layer to a nitrogen-containing gas at a temperature of about 700°C. to about 900°C., a pressure of about 1 to about 760 Torr, and a flow rate of about 100 to about 10,000 sccm, for about 1 second to about 180 minutes to nitridize the silicon layer to form the nitride dopant diffusion barrier layer, said barrier layer effective to inhibit passage of a dopant

into the dielectric material, the dopant diffusion barrier layer consisting of silicon and nitrogen overlying and interfacing with the dielectric material.

21. The method of Claim 20, wherein the nitrogen-containing gas is selected from the group consisting of nitrogen, ammonia, nitrogen trifluoride, nitrogen oxide, and a nitrogen-helium mixture.

98. The method of Claim 1, wherein the silicon-containing gas is selected from the group consisting of dichlorosilane, silicon tetrachloride, silane, and disilane.

99. The method of Claim 1, wherein exposing the dielectric material to the silicon-containing gas comprises chemical vapor deposition of the silicon gas.

100. The method of Claim 1, wherein exposing the dielectric material to the silicon-containing gas comprises rapid thermal chemical vapor deposition of the silicon gas.

103. The method of Claim 1, wherein exposing the silicon layer comprises thermally annealing the silicon layer in a nitrogen-containing gas.

104. The method of Claim 1, wherein exposing the silicon layer comprises a temperature of about 700°C. to about 900°C.

105. The method of Claim 1, wherein exposing the silicon layer comprises a temperature of about 700°C. to about 900°C., a pressure of about 1 to about 760 Torr, and a flow rate of about 100 to about 10,000 sccm for about 1 second to about 180 minutes.

106. The method of Claim 1, wherein the nitrogen-containing gas is selected from the group consisting of nitrogen, ammonia, nitrogen trifluoride, nitrogen oxide, and a nitrogen-helium mixture.

112. The method of Claim 1, wherein exposing the dielectric material comprises a partial pressure of about 10^{-2} to about 10^{-7} Torr, a temperature of about 500°C. to about 700°C., and a duration of about 1 second to about 5 minutes.

IX. EVIDENCE APPENDIX

None.

X. RELATED PROCEEDINGS APPENDIX

None.